(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 January 2004 (29.01.2004)

PCT

(10) International Publication Number
WO 2004/008932 A1

(51) International Patent Classification[7]: A47L 9/16

(21) International Application Number: PCT/GB2003/003247

(22) International Filing Date: 21 July 2003 (21.07.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0216955.5 20 July 2002 (20.07.2002) GB
0311915.3 23 May 2003 (23.05.2003) GB

(71) Applicant *(for all designated States except US)*: **HOOVER LIMITED** [GB/GB]; Dragonparc, Abercanaid, Merthyr Tydfil, Mid Glamorgan CF48 1PQ (GB).

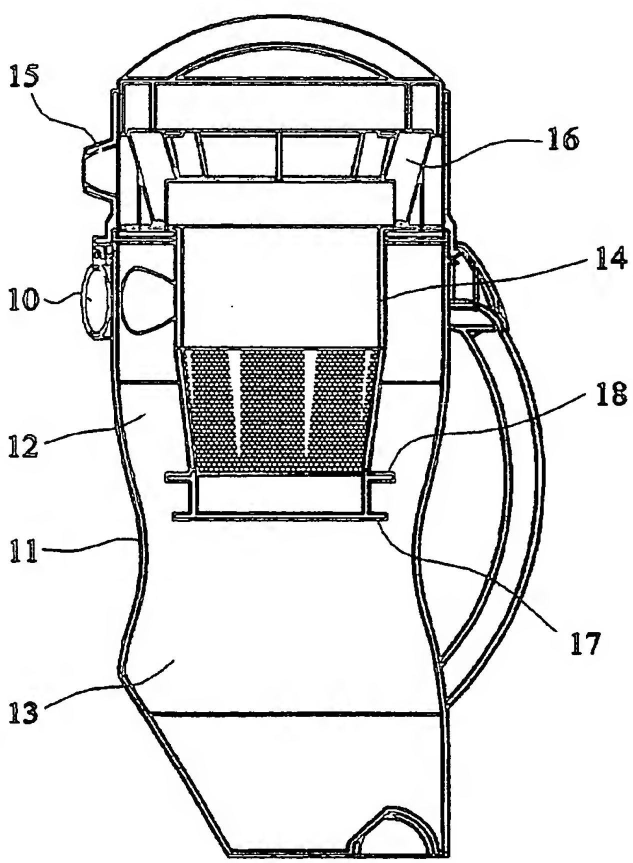
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **HASTIE, James** [GB/GB]; 25 Westfield Park, Strathavan, South Lanarkshire ML10 6XH (GB). **HENDERSON, Christopher** [GB/GB]; 2/R 30 Falkland Street, Hyndland, Glasgow G12 9QY (GB). **CHURCH, George** [GB/GB]; 60 Elm Drive, Llanellen, Abergavenny, Monmouthshire NP7 9HW (GB).

(74) Agent: **EVANS, Huw, David, Duncan**; Urquhart-Dykes & Lord, Three Trinity Court, 21-27 Newport Road, Cardiff CF2 0AA (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

[Continued on next page]

(54) Title: CYCLONIC VACUUM CLEANER



(57) Abstract: A vacuum cleaner comprises a cyclonic separator having a tubular wall (11) formed with a constriction intermediate its opposite ends between upper and lower regions (12, 13) of the separation chamber. The constriction helps to improve the separation efficiency of the cleaner and to avoid the re-entrainment of deposited dust.

WO 2004/008932 A1

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Cyclonic Vacuum Cleaner

This invention relates to a vacuum cleaner having a cyclone separator for separating dirt and dust particles from the airflow.

Vacuum cleaners incorporating one or more cyclone separators are well known. Typically such cyclone separators comprise an air inlet at a first end of the chamber, which feeds tangentially into a separation chamber having an outer wall which tapers inwardly away from the inlet towards the second end of the chamber. An air outlet extends axially from the first end of the chamber.

In use, dust laden air enters the cyclone chamber through the inlet, where it is forced around the curved wall of the chamber. The air swirls down the chamber in a cyclonic manner and the outward component of the force acting on particles suspended in the air tends to force particles in the flow against the outside of the wall of the chamber.

The outwards force acting on the particles in the chamber is governed by the following equation:

$$F \approx \frac{mv^2}{r}$$

where

F = the outwards force

m = the mass of the dust particle

v = the velocity of the dust particle

r = the radius of curvature of the airflow

Air is continuously being drawn radially inwards from the swirling airflow towards the outlet by the negative pressure at the outlet. This inward drag force attempts to re-entrain the separated particles back into the airflow. The

airflow rate and shape of the cyclone should be such that the outwards component F of the force acting on dust particles over a certain mass is greater than the inwards drag component. Accordingly, the separated particles should remain in the swirling flow against the wall of the chamber until they reach the bottom of the chamber, at which point all of the swirling airflow has drawn radially inwards and the flow has changed direction. At this point the swirling deposited particles enter a collection chamber.

The efficiency of any vacuum cleaner is defined as:

$$EFF_{SEP} = \frac{Dust\ Concentration_{In} - Dust\ Concentration_{Out}}{Dust\ Concentration_{In}} \times 100\%$$

The efficiency EFF_{SEP} of a cyclonic vacuum cleaner depends on the magnitude of the outwards component of the force acting to force dust particles towards the wall of the chamber and on the magnitude of the drag component of the force acting to re-entrain the separated particles back into the flow. Both of these forces are dependent on the velocity of the airflow (or the airflow rate).

It is evident from the above that small cyclones having a narrow radius of curvature have a higher separation efficiency than larger cyclones. Accordingly, whilst large low efficiency cyclones are suitable for separating large dust particles, smaller higher efficiency cyclones are required to separate the lighter smaller dust particles.

Hitherto, it has thus been common place to provide a low efficiency cyclone connected in series with a high efficiency cyclone. Thus arrangement is however bulky, complicated and costly to produce.

In order to overcome this problem it has been proposed to provide a single cyclone for removing a large proportion of the dust particles connected upstream of a filter which removes

any remaining dust particles. A disadvantage of this is that the filter has to be regularly cleaned or changed. Also, a large pressure drop can occur across the filter which substantially affects the airflow, especially when the filter becomes clogged.

It is therefore an object of this invention to provide a single separation stage for vacuum cleaner, which is capable of separating substantially all of the dust particles.

A large number of factors affect the separation efficiency EFF_{SEP}, with one of them being the amount of deposited dust in the collection chamber that is re-entrained due to secondary air flows being induced in the collection chamber.

Another factor affecting separation efficiency is the re-entrainment of separated dust within the cyclone chamber itself, which occurs when the inwards drag force of the airflow on the particles exceeds the outwards force.

Accordingly yet a further object of this invention is to produce a single stage cyclone separator having a high separation efficiency.

In accordance with this invention there is provided a vacuum cleaner incorporating a cyclone separator, the cleaner having an air inlet arranged to feed dust-laden air tangentially into one end of a chamber having a reduced diameter constriction intermediate opposite ends of the chamber, the chamber having first and second regions lying on respective opposite sides of the constriction, the diameter of the regions being greater than the diameter of the constriction, and means for creating a cyclonic airflow within at least a portion of the first region of the chamber.

We have found that a cyclone chamber having a constriction intermediate its opposite ends provides a high separation efficiency.

The first region of the chamber acts as a cyclone separator and the second region acts as a collection

compartment for the deposited dust. It will be appreciated that the diameter of the chamber is restricted between the two regions and this acts to suitably separate the regions, so that little or no airflow is induced in the second region where the dust is collected. Accordingly, the re-entrainment of deposited dust is avoided.

Any airflow which passes the narrowest point of the chamber will be constrained and thus the separated dust particles can move radially outwards away from the constrained cyclonic airflow, thereby alleviating the risk of re-entrainment of the separated particles by the radially inwards drag force.

The chamber preferably has a diameter, which reduces over said first region between the inlet and the constriction, and which subsequently increases over said second region towards the opposite end of the chamber.

Preferably, the diameter of the first region of the chamber is constant adjacent said inlet end.

Preferably the chamber comprises a tubular wall which is formed as one piece.

Preferably the rate at which the diameter of the wall increases and/or decreases axially of the chamber varies.

Preferably a circular core extends axially of the first region of the chamber.

Preferably the core comprises a tubular air outlet duct, having a wall which is preferably perforated.

Preferably the profile of the core substantially corresponds with the profile of the chamber, so that a substantially uniform gap is provided between the core and the chamber wall.

Preferably one or more circular baffles are mounted concentrically within the chamber at respective points intermediate opposite ends thereof.

Preferably the baffles are mounted at or between the constriction and a point in the first region where the diameter

of the chamber is constant.

Preferably, the gap between each of the baffles and the wall of the chamber is substantially uniform.

Embodiments of this invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a rear view of a body of a vacuum cleaner in accordance with this invention;

Figure 2 is a front view of the body of Figure 1; and

Figure 3 is a sectional view along the line III-III of Figure 2.

Referring to the drawings, a vacuum cleaner body comprises an inlet duct 10 carrying dust-laden air from a cleaning head tangentially into the upper end of a cyclonic separation chamber having a tubular wall 11.

The internal diameter of the wall 11 decreases over an upper region 12 of the chamber between its upper end and a point intermediate opposite ends of the chamber.

The internal diameter of the wall 11 may be constant over a central region of the chamber.

The internal diameter of the wall 11 then increases over a lower region 13 of the chamber towards the lower end thereof.

A tubular shroud 14 extends axially of the chamber from its upper end to a point intermediate opposite ends of the chamber. An outlet duct 15 is connected to the interior of the tubular shroud 14 via a filter assembly 16.

The external wall of the tubular shroud 14 is preferably perforated over its lower end, in order to allow air to flow from the chamber to the outlet 15 via the centre of the shroud 14. The radial distance between the external surface of the shroud 14 and the internal surface of the wall 11 of the chamber is preferably constant over a substantial part of the length of the shroud 14.

A flange extends radially outwards around the periphery

of the lower end of the shroud 14 to form a first baffle 17, which is located at or above the narrowest diameter portion of the chamber.

A further flange extends radially outwards around the periphery of the lower end of the shroud 14 to form a second baffle 18 which is of a greater diameter than the first baffle 17 and which is located above the first baffle 17 in the upper region 12 of the chamber, at a point where the diameter of the chamber is reducing. The radial distances between the baffles 17,18 and their respective points on the chamber wall 11 are preferably substantially equal.

In use the outlet 15 is connected to a fan which draws air through the inlet 10 and out of the chamber. The tangential orientation of the inlet 10 with respect to the wall 11 of the chamber creates a cyclonic airflow, whereby air spirals downwardly around the chamber towards its lower end. As the air flows downwards, the volume of air in the spiral flow is constantly being diminished by virtue of it having been drawn radially through the perforated shroud 14 towards the outlet 15.

At a point adjacent the central portion of the chamber, substantially all of the swirling air has been drawn through the shroud 14.

As the air swirls, dirt and dust in the airflow are forced radially outwardly against the interior of the wall 11 by the radially outwards component of the force acting on the particles. The dirt and dust thus separated remains in an edge zone of the chamber and is carried downwardly by the flow until it reaches the point where the cyclonic flow ceases, whereupon the dirt and dust is deposited in the lower region 13 of the chamber.

The divergent nature of the wall of the lower region 13 of the chamber helps to ensure that the deposited dust therein is not re-entrained by secondary air flows induced in the lower region 13 of the chamber.

Any cyclonic airflow which extends into the lower region 13 of the chamber is suitably constrained by the narrow central region of the chamber and does not fully expand into the outer perimeter of the lower portion 13 of the chamber.

Accordingly, separated dust particles that are held against the wall of the chamber in its upper region, as hereinbefore described, move into a peripheral region of the lower region 13 of the chamber and out of the cyclonic flow, where they are no longer subjected to the radially inwards drag force that draws them towards the outlet.

In this manner, the re-entrainment of separated dust particles is avoided and the particles fall to the bottom of the chamber.

A cyclone separator having a convergent- divergent wall in accordance with this invention has a substantially improved separation efficiency and thus helps to alleviate the need for a secondary separation stage. However, in cases where the filter 16 is provided, it will be appreciated that the filter is less liable to clogging owing to the high separation efficiency of the cyclone stage.

Claims

1. A vacuum cleaner incorporating a cyclone separator, the cleaner having an air inlet arranged to feed dust-laden air tangentially into one end of a chamber having a reduced diameter constriction intermediate opposite ends of the chamber, the chamber having first and second regions lying on respective opposite sides of the constriction, the diameter of the regions being greater than the diameter of the constriction, and means for creating a cyclonic airflow within at least a portion of the first region of the chamber.

2. A vacuum cleaner as claimed in claim 1, in which the chamber has a diameter, which reduces over said first region between the inlet and the constriction, and which subsequently increases over said second region towards the opposite end of the chamber.

3. A vacuum cleaner as claimed in claims 1 or 2, in which the diameter of the first region of the chamber is substantially constant adjacent said inlet end.

4. A vacuum cleaner as claimed in any preceding claim, in which the chamber comprises a tubular wall, the rate of change of the diameter varying axially of the chamber.

5. A vacuum cleaner as claimed in any preceding claim, in which a core extends axially of the first region of the chamber.

6. A vacuum cleaner as claimed in claim 5, in which the core comprises a tubular air outlet duct.

7. A vacuum cleaner as claimed in claims 5 or 6, in which the profile of the core substantially corresponds with the

profile of the chamber, so that a substantially uniform gap is provided between the core and the chamber wall.

8. A vacuum cleaner as claimed in any preceding claim, in which one or more circular baffles are mounted concentrically within the chamber at respective points intermediate opposite ends thereof.

9. A vacuum cleaner as claimed in claim 8, in which the baffles are mounted at or between the constriction and a point in the first region where the diameter of the chamber is substantially constant.

10. A vacuum cleaner as claimed in claims 8 or 9, in which the gap between each of the baffles and the wall of the chamber is substantially uniform.

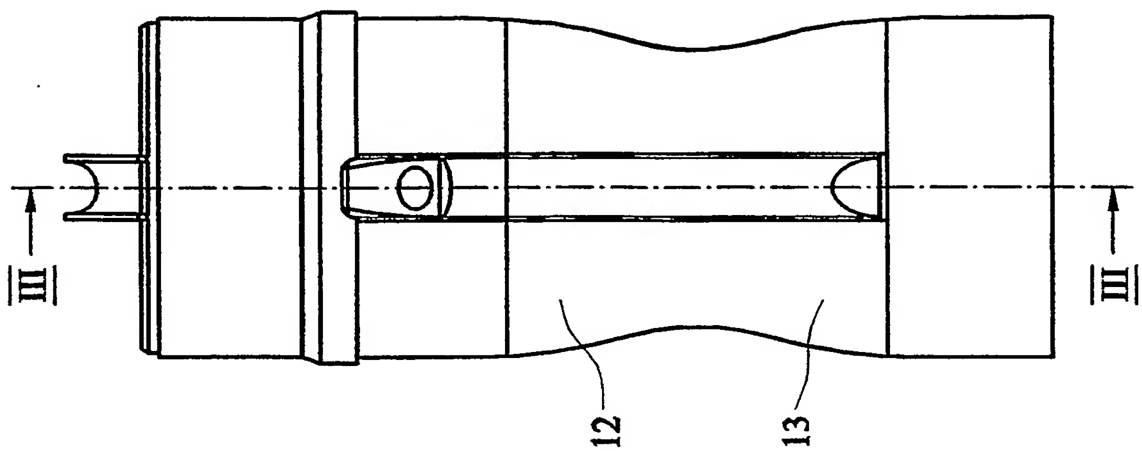


FIG. 2

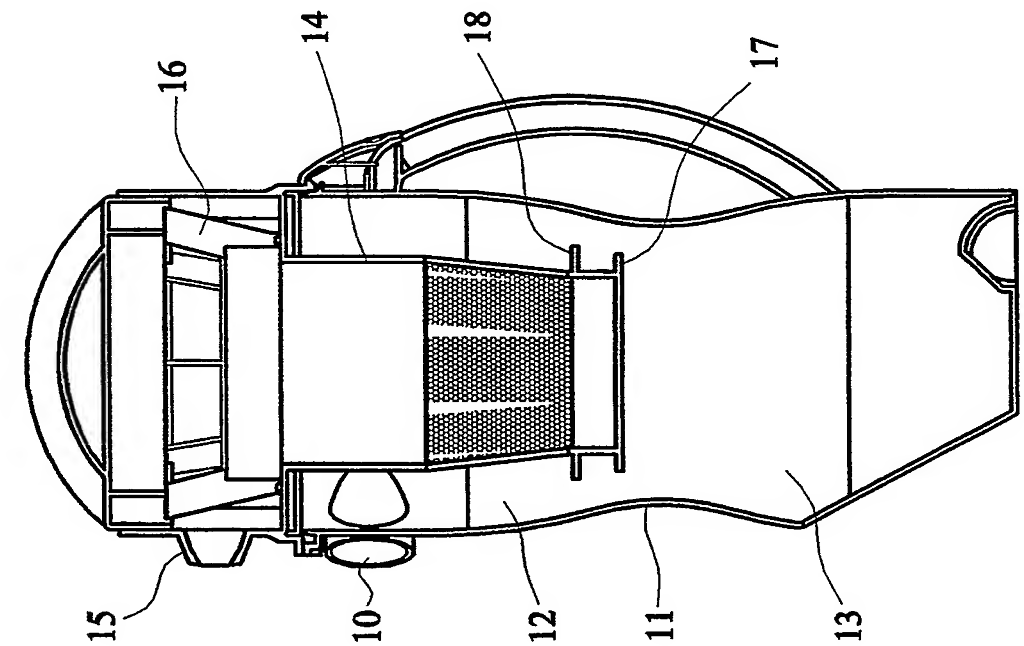


FIG. 3

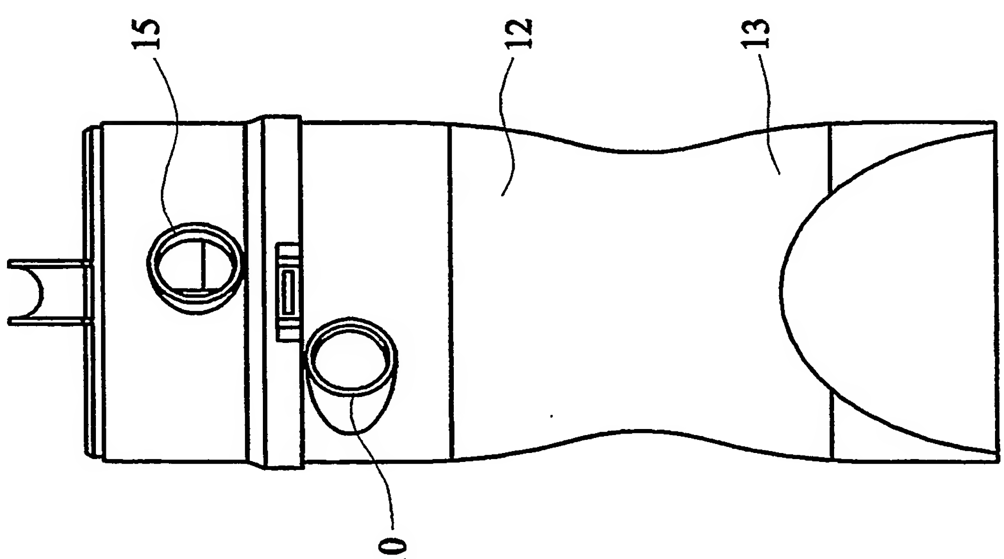


FIG. 1

INTERNATIONAL SEARCH REPORT

Inte[redacted]onal Application No
PCT/GB 03/03247

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A47L9/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A47L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 1 274 656 A (GRIMAUD ANDRE) 27 October 1961 (1961-10-27) the whole document	1-10
X	EP 0 885 585 A (CANDY SPA) 23 December 1998 (1998-12-23) column 3, line 2 -column 3, line 53; figures 1,3	1-6
A	US 5 307 538 A (RENCH GEOFFREY B ET AL) 3 May 1994 (1994-05-03) column 8, line 11 -column 8, line 22; figures 5,6,8	7
A	US 5 858 038 A (THOMSON ANDREW WALTER MCRAE ET AL) 12 January 1999 (1999-01-12)	

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 November 2003	09/12/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Martin Gonzalez, G

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/03247

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	GB 672 328 A (BRITISH THOMSON HOUSTON CO LTD) 21 May 1952 (1952-05-21)	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 03/03247

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
FR 1274656	A	27-10-1961	FR	79154 E	03-11-1962
EP 0885585	A	23-12-1998	US	6083292 A	04-07-2000
			EP	0885585 A1	23-12-1998
			DE	69712046 D1	23-05-2002
			DE	69712046 T2	05-12-2002
			ES	2171875 T3	16-09-2002
US 5307538	A	03-05-1994	AT	163521 T	15-03-1998
			DE	69224666 D1	09-04-1998
			DE	69224666 T2	25-06-1998
			DK	634905 T3	07-12-1998
			EP	0634905 A1	25-01-1995
			JP	7505312 T	15-06-1995
			WO	9319659 A1	14-10-1993
US 5858038	A	12-01-1999	AU	695149 B2	06-08-1998
			AU	4269496 A	10-07-1996
			AU	703206 B2	18-03-1999
			AU	4269596 A	10-07-1996
			CA	2221498 A1	27-06-1996
			CA	2222537 A1	27-06-1996
			DE	69516539 D1	31-05-2000
			DE	69516539 T2	18-01-2001
			DE	69519391 D1	14-12-2000
			DE	69519391 T2	05-07-2001
			EP	0799093 A1	08-10-1997
			EP	0799094 A1	08-10-1997
			WO	9619293 A1	27-06-1996
			WO	9619294 A1	27-06-1996
			GB	2296206 A	26-06-1996
			JP	10510756 T	20-10-1998
			JP	10510757 T	20-10-1998
			ZA	9510864 A	30-05-1996
GB 672328	A	21-05-1952	FR	1013999 A	06-08-1952

THIS PAGE BLANK (USPTO)